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Natural Resource Accounting For The National Forests: A Conceptual Framework

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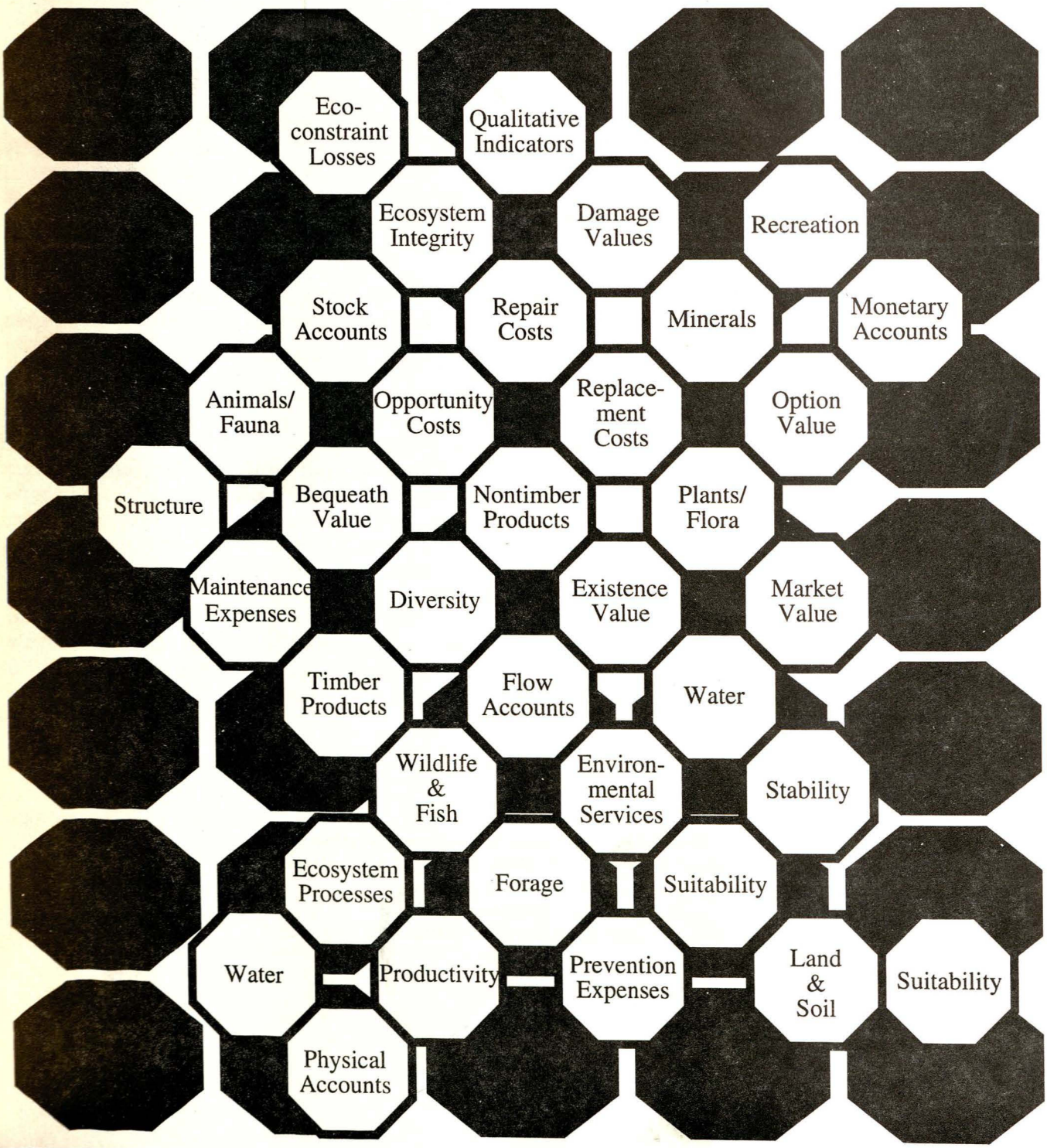

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Summarizes the shortcomings of current natural resource accounting systems, outlines some of the features needed, and proposes an accounting framework that would help integrate economic and ecological factors. Such a system of forest resource accounting is urgently needed to achieve the sustainable goals of ecosystem management.

KEY WORDS: Natural resource accounting, environmental accounting, forest resource accounting, sustainability goals.

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The sustainability of natural resources has been an important concern in our society. In the last decade, however, the public began shifting its focus toward a new environmental paradigm (Wilkerson and Edgell 1993, Dunlap and van Liere 1984). Our approach to sustainability in forest management is also shifting. For example, the concept of *sustained yield* has traditionally reflected our concern for the Nation's timber stocks. But today, that notion of sustained yield fails to fully capture the many functions and values of forest ecosystems.

The new environmental paradigm stresses the need for harmony between society and nature (Brown and Harris 1992). In forestry, this new paradigm is called *New Perspectives, Sustainable Forestry,* and *Ecosystem Management*, and other names. It embodies a constellation of new and interlocking beliefs, values, and techniques for managing natural resources; clarifies what is important; and provides a rationale for collecting, organizing, and using information. Forest policy makers need to be better informed about this new focus to achieve economic, social, and environmental objectives while balancing human needs and aspirations with ecosystem constraints. Forest resource accounting systems (FRA) could be a tool to meet the challenge of using multidimensional information to measure the health of both forest ecosystems and economic systems. Figure 1 illustrates the relationship between the changing paradigm of resource management and the needs of resource accounting.

A forest ecosystem can be viewed as natural capital that has the capacity to provide a wide spectrum of social benefits through its diverse components, various processes, and multiple functions. In this light, the sustainability of natural capital can be considered as the maintenance of its productive capacity (Solow 1992). The income or income equivalence (beneficial impacts) from various attributes of forest ecosystems may be assessed and aggregated to provide key indices for monitoring the sustainability of forest capital over time. This income-producing capacity of forest ecosystems can be linked to the national accounts to more accurately reflect the actual contributions of forest ecosystems to the Nation's economy.

The productive capacity of forest capital depends on both the functional integrity of forest ecosystems and a broad range of social factors such as values and technology. Values reflect what is important to society, and the values we place on nature reflect what our priorities are. At the same time, improvements in technology can lead to new values. From timber to multiple functions, the uses of forests have been growing as a result of changing values and technology.

The capacity of forest ecosystems as natural capital may or may not be enhanced as changes in social factors occur. To ensure such enhancement, the functional integrity of forest ecosystems must be maintained. A forest resource accounting system grounded in the key concept of natural capital would help reshape forest policies to provide an even wider spectrum of

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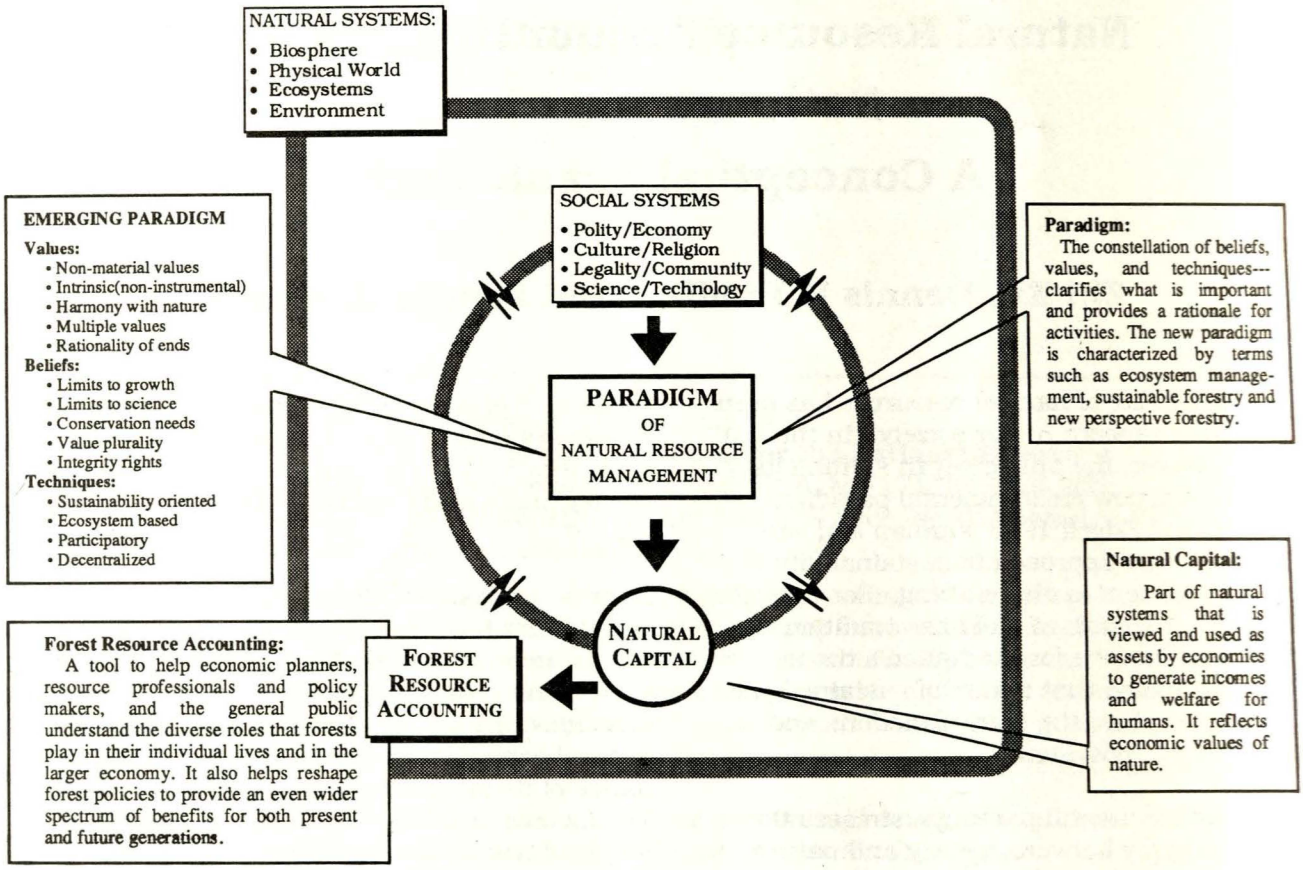
NATURAL SYSTEMS:
• Biosphere
• Physical World
• Ecosystems
• Environment
EMERGING PARADIGM
Values:
• Non-material values
• Intrinsic(non-instrumental)
• Harmony with nature
• Multiple values
• Rationality of ends
Beliefs:
• Limits to growth
• Limits to science
• Conservation needs
• Value plurality
• Integrity rights
Techniques:
• Sustainability oriented
• Ecosystem based
• Participatory
• Decentralized
SOCIAL SYSTEMS
• Polity/Economy
• Culture/Religion
• Legality/Community
• Science/Technology
PARADIGM
OF
NATURAL RESOURCE
MANAGEMENT
NATURAL
CAPITAL
FOREST
RESOURCE
ACCOUNTING
Paradigm:
The constellation of beliefs, values, and techniques---clarifies what is important and provides a rationale for activities. The new paradigm is characterized by terms such as ecosystem management, sustainable forestry and new perspective forestry.
Natural Capital:
Part of natural systems that is viewed and used as assets by economies to generate incomes and welfare for humans. It reflects economic values of nature.
Forest Resource Accounting:
A tool to help economic planners, resource professionals and policy makers, and the general public understand the diverse roles that forests play in their individual lives and in the larger economy. It also helps reshape forest policies to provide an even wider spectrum of benefits for both present and future generations.

Figure 1.—*Forest Resource Accounting: meeting the challenge of the new paradigm.*

benefits for present and future generations by maintaining and enhancing the capacity of forest capital. Such an accounting system would identify forest ecosystem assets, register natural income flows, and link these assets and flows to national accounts. As a result, we would be better able to maintain the productive capacity of forest capital and the integrity of forest ecosystems, to relate present income to future potentials, to monitor the dynamics of natural resource assets, and to evaluate management objectives and actions more realistically.

By providing formatted and organized information to policy makers and resource managers, forest resource accounting helps answer the questions such as: Can we differentiate growth and development? Are growth and development incompatible? How are social, economic, and environmental processes best linked to achieve sustainable development? How can we measure these linkages to judge future developmental prospects?

Within the Forest Service, the focus on sustainability has broadened as a result of the Agency's ecosystem management initiative (USDA 1992, FEMAT 1993). Over the past 3 decades, in response to increasing and often conflicting demands, the Forest Service has developed a practice of multiple-use that seeks to provide the greatest resource benefits for the broadest segment of American people (USDA 1990a). Multiple-use management has brought a more rigorous and consistent application of economics to national forest management. Although multiple-use recognizes the linkages between forest ecosystems and economic systems, the sustainability of the forest as a key source of inputs to the economic system was not a concern at this level of consideration. Presumably, modern forest management theory had already settled this concern by developing empirically based *sustained yield* practices. It is only more recently that many have recognized that multiple-use management must rest on ecosystem approaches.

Although an ecosystem approach to multiple-use management is ambiguous and still evolving, it does stress that the continued flows of all forest goods and services depend on the continuation of the multiple functions and processes that constitute forest ecosystems. Avers (1992) defined ecosystem management as the skillful, *integrated* use of ecological knowledge at various scales to produce desired resource values, products, services, and conditions in ways that also sustain the diversity and productivity of ecosystems. And, to the extent that the increasingly more difficult management issues and resource concerns reflect shortcomings in our understanding of ecosystems, ecosystem management is seen as a necessary step to resolving these difficulties.

If ecosystem management is an attempt to link social systems (most often characterized by economic systems) and ecosystems, then one of the first tasks of ecosystem management would be to provide integrated sets of data that link economic and ecological processes (Overbay 1992). Forest resource accounting systems may provide such information to help economic planners, resource professionals, and the general public understand the diverse roles that national forests in particular, and forests in general, play in people's lives and in the national economy.

We currently have in place various national and regional macroeconomic accounting systems that have demonstrated their value for measuring internal economic conditions and trade linkages with other economic entities. However, existing national income accounts neglect changes to the productive capacity and welfare roles of natural resources and the environment. They are of limited use for gauging the possibilities for long-term sustainable growth because they ignore natural resource depletion and degradation (El Serafy and Lutz 1989). More specifically, they do not reflect (1) the full scope of the production roles played by natural resources and ecosystems, (2) the broader welfare implications of natural resources and ecosystems beyond the economic, (3) the often obscure environmental services and functions that ecosystems also provide for themselves and for us, and (4) most important, the impacts of current economic activity on future natural resource potentials and ultimately on future development prospects.

To correct some of these shortcomings, changes to these accounting systems have been proposed that would more realistically measure economic performance as well as help to implement sustainable natural resource and environmental management. As an operational tool to sustainable development, a natural resource and environmental accounting approach has been widely discussed (Repetto *et al.* 1989, El Serafy and Lutz 1989, Bartelmus 1989, Peskin 1990, Costanza and Daly 1990, Daly and Cobb 1989, Daly 1991, and Solow 1992). In this paper, we will briefly (1) justify the need for a more complete system that combines existing economic accounts with additional indicators of environmental and ecosystem conditions, (2) review the basic features of an NREA system, (3) elaborate duality of forests as ecosystems and capital, and (4) sketch a conceptual framework of forest resource accounts for the National Forest System that would at least move toward integrating economic and ecological factors.

NATURAL RESOURCE AND ENVIRONMENTAL ACCOUNTING: A BRIEF REVIEW

Shortcomings of Existing Economic Accounts

There are several problems with the way we define natural resources and measure their contribution to current national economic activities. If sustainability and ecosystem management are to be anything more than slogans, they must require us to preserve the productive capacity of capital (both human-made capital and natural resources) for the indefinite future (Solow 1992). The distinction between human-made and natural capital is crucial because it underlines the limited substitutability between them (Daly and Cobb 1989). This is in strong contrast to the neoclassical assumption of unlimited substitutability. By explicitly treating natural resources and environments as capital, these newer notions of sustainable development recognize that productive capacity in the future depends on maintaining productive capacity now.

Current national economic accounts have a very narrow view of income, defining "income" generated by each economic activity as revenue minus all the costs of intermediate inputs. However, in the case of natural resource exploitation, "income" is defined as revenue minus the cost of

extraction only—all other aspects of the real and potential utility of these resources are ignored. In particular, any reductions that may have occurred in the productive capacity of such resources are not subtracted from the income accounts. Therefore, income accounts are exaggerated—in effect, treating depreciation (of the natural resource and the environment) as income. By this oversight, countries may exhaust their minerals, overcut their forests, erode their soils, pollute their aquifers, and hunt their wildlife and fish to extinction, while their 'income' seems to increase (Repetto *et al.* 1989).

Many other important economic effects related to natural resources and the environment are not reflected in existing national accounts. Although market transactions reflect the limited economic quality of a natural resource and its related environmental services, quality in general is ignored by national income accounts. For example, tree size or iron ore content is reflected in the value of business inventories because these qualities have a direct link to market price. But characteristics such as the role played by trees in the future productivity of the forest ecosystem as a whole or the unavoidable impacts, if any, of mining on the outputs of adjacent ecosystems, are not considered. Moreover, because national income indicators are treated as a proxy for welfare based on assumptions about the effectiveness of mechanisms of redistribution such as the tax system, accounts ought to reflect the costs incurred by society when natural resources and the environment are degraded. Similarly, these accounts ought to reflect the gains from improving natural resource and environmental quality.

Because current economic accounting systems focus heavily on income, they underestimate the value of natural resources and environmental assets and their contribution to the current and future economy. This underestimate results in disinvestment and eventually reduces the contributions of natural resources to future economies. If the potential benefits of natural resources and ecosystems were recognized and converted into actual benefits as a society and its economy develop, then more of these values would be appreciated. But many of these potential benefits may be lost forever. For example, if a forest ecosystem is treated as only timber, land, water, and other items of immediate use to an economy, many other less obvious but no less important ecosystem goods and services will be neglected (Xu and Bradley 1993). An immediate practical consequence of these accounting shortcomings for the Forest Service is the difficulty in justifying its budget requests when confronted with the often more compelling and immediate evidence from other interest groups. An improved system of accounts could substantially bolster the Agency's claims for public support.

In short, information generated from current national accounts misleads resource and environmental policies, causing underinvestment and mismanagement, which endanger sustainable development. Thus, a major objective of natural resources and environmental accounting is to develop a system of accounts that can appropriately reflect more, if not all, changes in the uses, roles, and capacities of natural resources and the environment in terms of their possible effect on sustainable development.

Basic Features of NREA

Various proposals have been made for a new system of natural resource and environmental accounting (NREA) that can make sustainable development and environmental management feasible in practice (Ahmad 1989). As briefly outlined above, natural resources and the environment should be viewed to a greater extent as capital (Costanza and Daly 1990, El Serafy 1991). And given such a perspective, it is more likely that we will achieve economic sustainability by maintaining the productive capacity of both natural and human-made capital (Hicks 1946 and 1974, Solow 1992). NREA would link economic activity and natural resources and environmental management to macroeconomics analyses by estimating changes to the various capacities of natural resources and the environment, and constructing income indicators deducting necessary depreciation from both natural and human-made capital.

In general, a system of NREA would track changes in the quantity, quality, and value of natural resources and environmental assets (Anielski 1991). Ideally, such an accounting system would provide an opening stock situation, the flows to and from these stocks (including depletion, additions, degradation and appreciation), and a closing balance for all the attributes

of multifunctional natural resource ecosystems such as forests. Because many attributes are intangible, the alternative way is to develop linkage accounts that tie changes in ecosystem health to changes in economic health. Such accounts would no doubt improve natural resource management and national development policies.

The various approaches to NREA reflect, to some extent, the balance between policy goals and the costs of attaining these goals (Peskin 1990). They can be summarized into three broad categories: (1) economic, (2) physical, and (3) integrated economic and physical approaches (Gilbert and Hafkamp 1986). Economic approaches have concentrated on modifying indicators in the current system of national accounts (SNA) to better reflect the roles of natural resources and the environment in such accounts as gross domestic product (GDP) and gross national product (GNP) (Olson 1977, Peskin 1981, Hueting 1974, Repetto *et al.* 1989, Bartelmus *et al.* 1992). But much important information is not economic, and therefore cannot be adequately interpreted using economic approaches. Moreover, many resource and environmental dynamics may be described better in physical terms.

The physical approach to accounting for natural resource stocks and flows avoids the difficulties of assigning monetary values to all transactions, but its role in decision/policy analysis is limited because it excludes economic information. However, the physical approach can complement economic accounts. Therefore, the mainstream tendency is to integrate both economic and physical accounts in natural resource accounting.

The feasibility of integrating monetary and physical accounts for natural resources and the environment was explored by Hueting (1980), Peskin (1989), and Bartelmus *et al.* (1989). It was also discussed in workshops jointly organized by the United Nations Environmental Program (UNEP) and the World Bank. A consensus was reached there that enough progress had been made in linking environmental accounting to the U.N. System of National Accounts to include certain aspects of environmental accounting in the ongoing revision of the SNA called the System of Integrated Environmental-Economic Accounting (SEEA) (Bartelmus *et al.* 1992). This new system incorporates natural resources and environmental information into major national accounts. Three types of accounts for natural resources and environmental assets are included as satellite accounts established within the framework of SEEA: (1) physical accounts, (2) environmental quality indicator accounts, and (3) monetary (value) accounts.

Bartelmus *et al.* (1992) conducted a case study to demonstrate this new system. The recently released "Caring for the Earth - A Strategy for Sustainable Living" (IUCN *et al.* 1991) recommends NREA as part of a program for achieving sustainable living by building a framework that explicitly links and integrates development and conservation (Anielski 1991). NREA is being considered or developed in France, Norway, Japan, Indonesia, Costa Rica, New Guinea, Canada, and China (Repetto *et al.* 1989, Repetto 1992, Bartelmus *et al.* 1992, Theys 1989, Foy 1991, Anielski 1993, and others).

A FOREST RESOURCE ACCOUNTING PROPOSAL

Forest Capital and Its Dual Capacity[1]

Forest-related accounts are the major components of NREA. Before we can develop a National Forest Resource Account, we must be clear about assumptions and terms. From an ecological perspective, forests are terrestrial ecosystems with trees as the largest component, but also including many other plants, animals, microbes, and a complex abiotic physio-chemical base. From an economic perspective, forests are capital. The income-producing capacity of forests as natural capital can be characterized as an ***actual*** capacity and a ***potential*** capacity, and this distinction is an important one.

We currently use forests and other ecosystems to produce a variety of goods and services that generate income streams today. Those goods and services that have already been discovered and used are the ecosystem's actual capacity (the downward flowing arrows in figure 2). However, as society develops and new needs emerge, we will use ecosystems in ways we do not currently

[1] *See Xu and Bradley (1993) for a more detailed discussion of forest capital theory.*

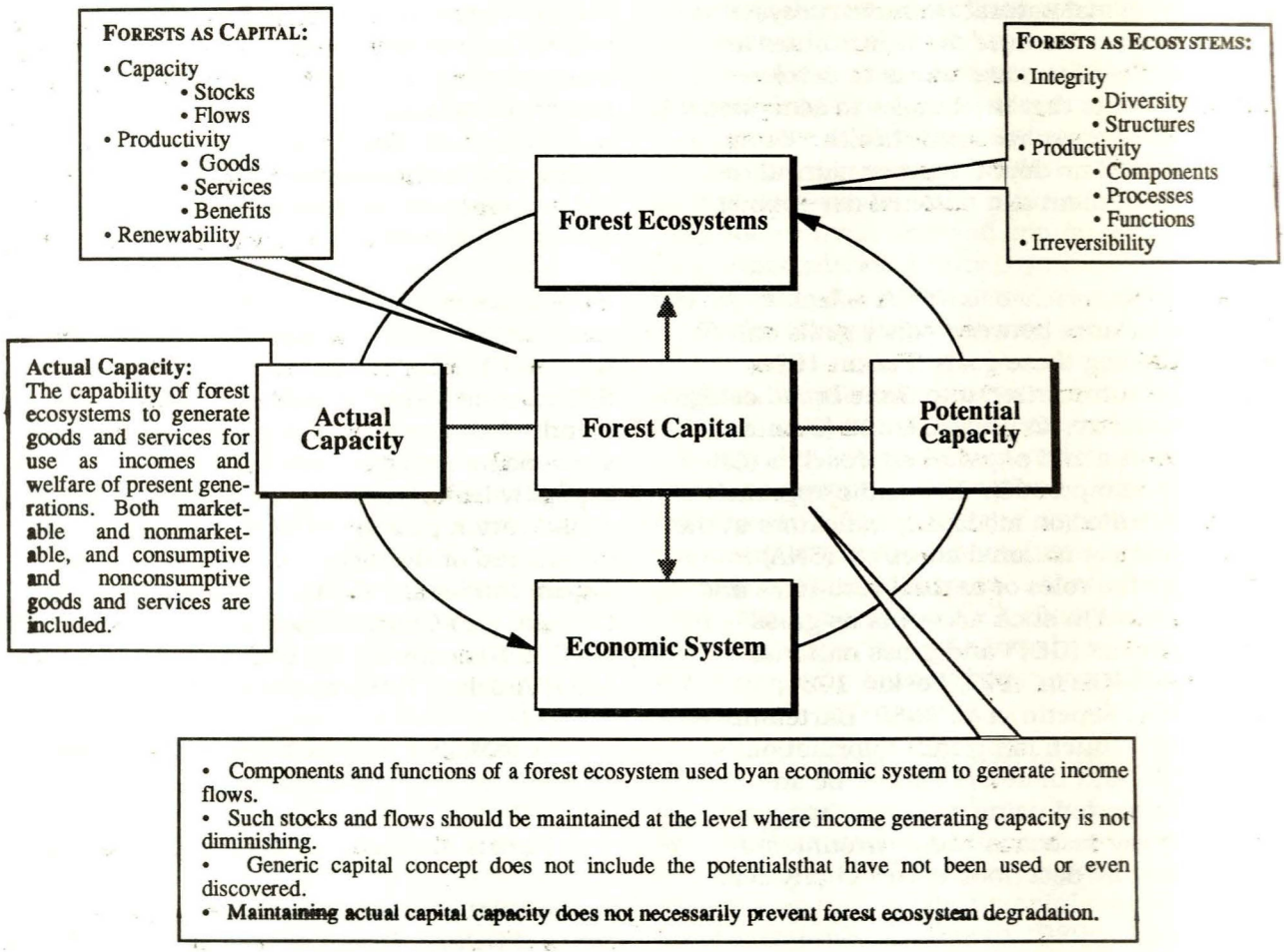
FORESTS AS CAPITAL:
• Capacity
• Stocks
• Flows
• Productivity
• Goods
• Services
• Benefits
• Renewability
FORESTS AS ECOSYSTEMS:
• Integrity
• Diversity
• Structures
• Productivity
• Components
• Processes
• Functions
• Irreversibility
Forest Ecosystems
Actual Capacity:
The capability of forest ecosystems to generate goods and services for use as incomes and welfare of present generations. Both marketable and nonmarketable, and consumptive and nonconsumptive goods and services are included.
Actual Capacity
Forest Capital
Potential Capacity
Economic System
• Components and functions of a forest ecosystem used byan economic system to generate income flows.
• Such stocks and flows should be maintained at the level where income generating capacity is not diminishing.
• Generic capital concept does not include the potentialsthat have not been used or even discovered.
• Maintaining actual capital capacity does not necessarily prevent forest ecosystem degradation.

Figure 2.—*Forests as capital and ecosystem: duality.*

understand or anticipate. The future income streams from these as-yet undiscovered uses are an ecosystem's potential capacity (upward flowing arrows in figure 2). This actual and potential capacity has been referred to as the duality of natural capital (Xu and Bradley 1993).

From such a perspective, forest ecosystem goods and services—actual or potential—are viewed as income to some user—present or future. The actual contribution of a forest ecosystem to the present economy is less than its potential because some, perhaps even most, of its goods and services have not been discovered and used and therefore cannot be valued by the present economy. However, if our measures of income do not at least attempt to account for these potentials, natural capital will be undervalued. Such undervaluation could result in depletion or degradation of natural capital; and it could violate capital theory's sustainability principle because future income flows would no longer be maximized and the welfare of future generations would be reduced. Thus, in measuring a forest's income capacity, we must consider its dual character: both actual and potential capacities.

To ensure that ecosystem products and services are available to future generations, we need to be able to ensure—to the extent possible—that future forest values do not decrease. Because future value estimation is still in question, perhaps the best we can do now is to guarantee or sustain the potential productive capacity of a forest ecosystem by maintaining a forest ecosystem's functional integrity. In a real sense, the Forest Service's ecosystem management initiative can be thought of as an attempt to operationalize these concerns about actual and potential capacity of forests by maintaining this functional integrity.

Forest Resource Accounts

A more robust set of forest resource accounts (FRA) would attempt to link the various functions of forests as ecosystems with the actual and potential income-producing capacity of forests as capital (fig. 3). Such accounting would help forest managers fulfill their role in sustaining both forest-dependent economies and ecosystems.

The Forest Service uses an ecosystem approach to multiple-use management to meet a broad spectrum of human needs. Some of the products and services provided by forest ecosystems are measured in economic terms by the current system of national accounts, which give an important but only partial picture of economic health (the left outer loop in figure 3). Potentials, on the other hand, are measured by noneconomic measures, with environmental and ecological indicators providing some clue to ecosystem health (the right outer loop in figure 3). Only by considering both economic and ecosystem health will we be able to achieve sustainable development.

Forest resource accounts would serve as links for economic performance and ecosystem health by evaluating both the actual and potential capacities of forest ecosystems (the center box in figure 3). The actual capacity of the forest ecosystem is best measured by the economic and physical quantities and prices of forest goods and services that have been discovered and are currently in use. But actual capacity is tied to a particular period in an economy's development and to a specific level of ecosystem development. To

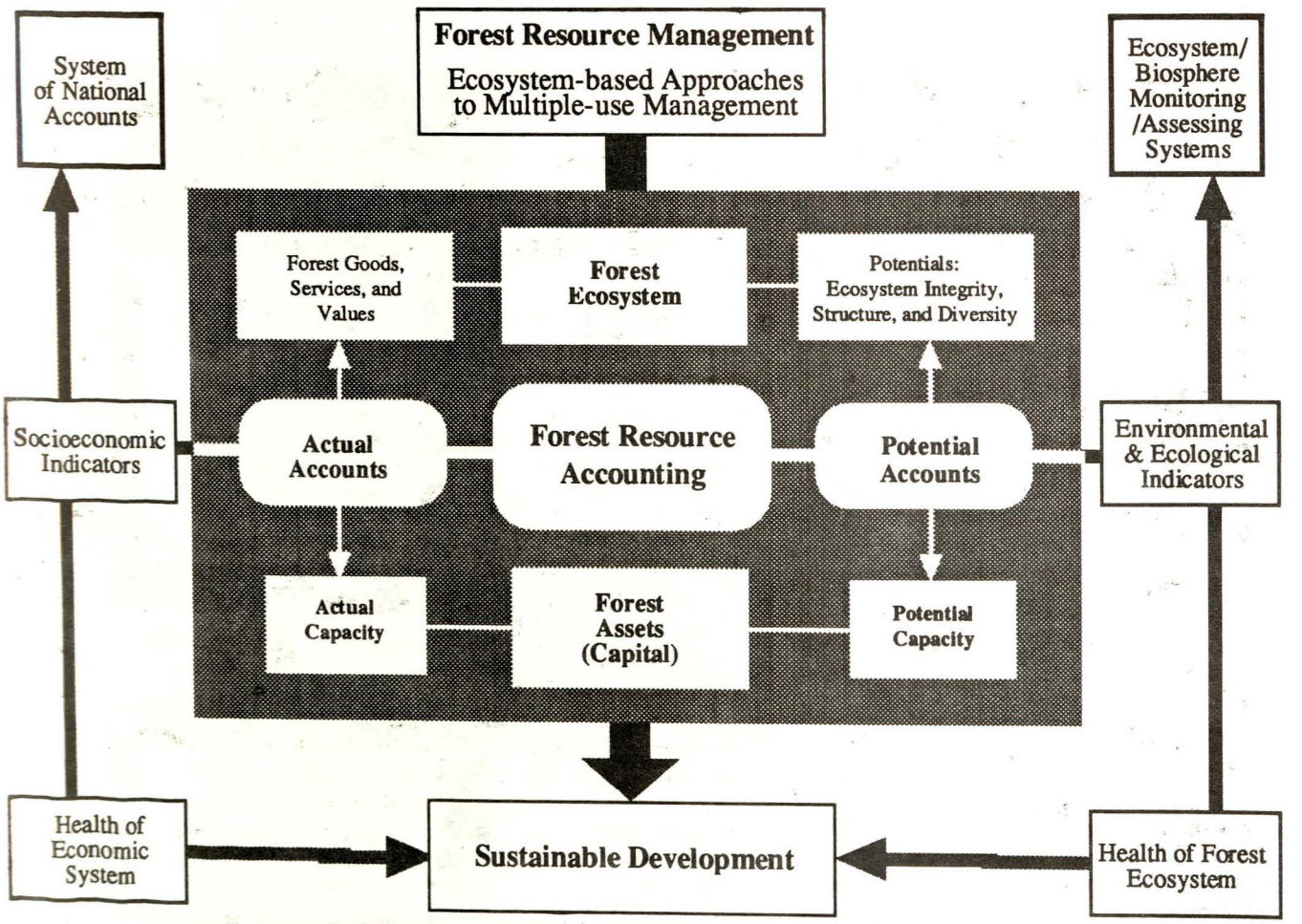

Figure 3.—*Forest Resources Accounts, forest resource management, and sustainable development.*

account for future changes in our economic needs and expectations, we must also account for the potential capacity of forest ecosystems. As discussed earlier, perhaps the only way to accomplish this second task now is to maintain functional integrity of forest ecosystems.

Three Facets of a Forest Resource Account

Let's consider the FRA (the center shaded box in figure 3) in more detail. To link a forest ecosystem's actual and potential capacities, we will need the two sets of measures we've already mentioned—(1) a set of economic accounts and (2) a set of environmental and ecological indicators for various conditions important to the continued productivity and health of forest ecosystems—and a third set of measures we refer to as linkage accounts that would track the economic costs and other consequences of maintaining (or avoiding) the previously identified ecological conditions (or dysfunctions). Figure 4 provides a simplified framework of such a system.

1. Actual Capacity Accounts

In line with our earlier discussion about the duality of ecosystem features and characteristics, the first type of account would measure the flows of forest ecosystem goods and services that are actually used by the current economy and may be termed the Actual Capacity Accounts. This flow of goods and services can be assessed by their economic value (monetary accounts) and the physical units on which the economic value is based (physical accounts). In addition, both monetary and physical accounts should be divided into flow and stock accounts to more realistically monitor the dynamics of asset stocks and flow.

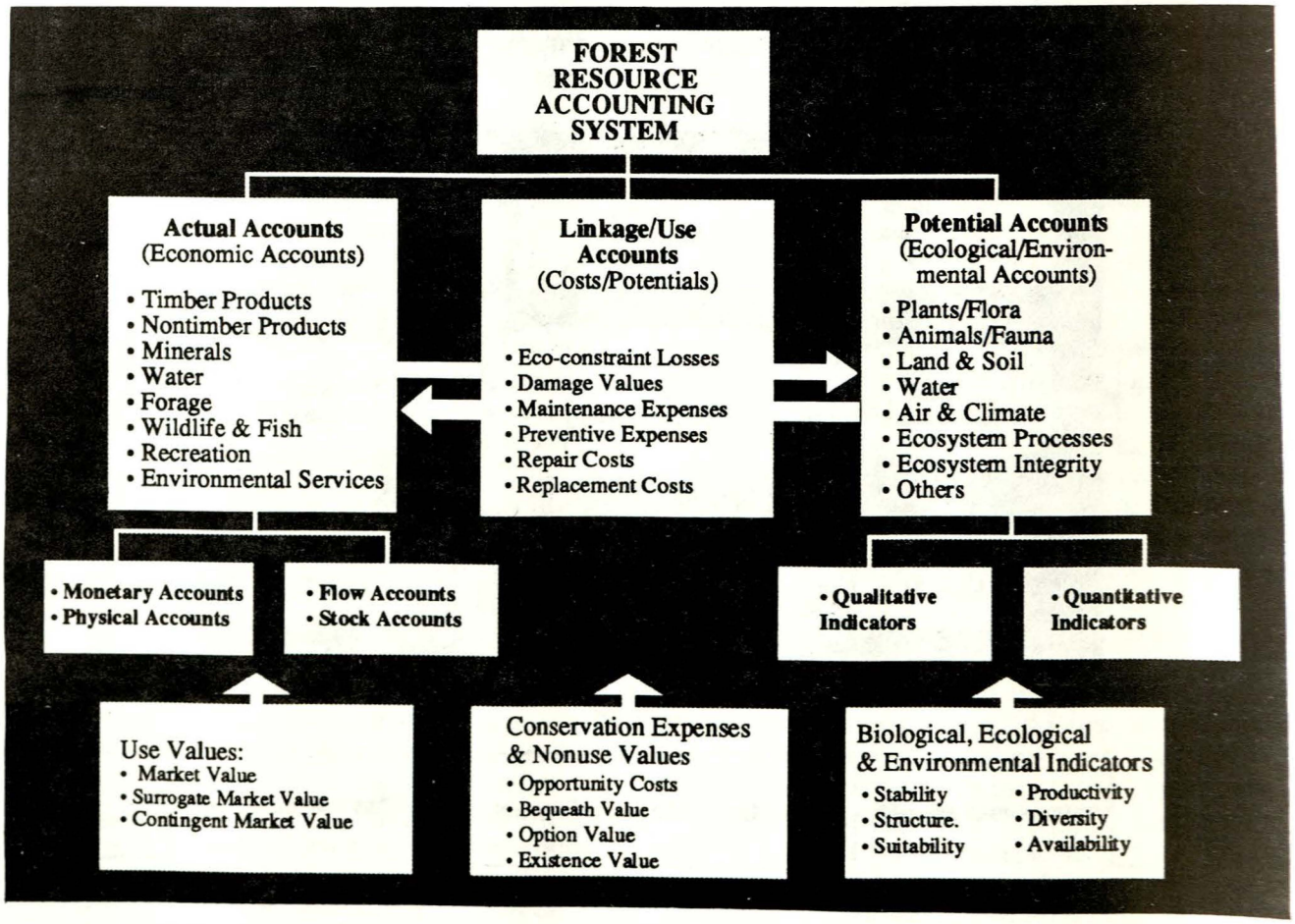

Figure 4.—*Three kinds of Forest Resource Accounts.*

Monetary accounts can be established for those goods and services for which there is a market, but they also may be established for goods and service for which there are no markets or only imperfect ones. The economic benefits provided by these non-market goods and services can be observed and measured using valuation techniques such as surrogate market approaches, contingent market approaches, etc.; these have been used for national forest planning (Bishop 1987, Johnson and Johnson 1990, Peterson and Randall 1984, USDA 1990b).

Physical accounts are also useful to forest managers and are generally more comprehensible to the general public than many economic accounts. In many cases of ecosystem goods and services, physical accounts are the best we can do. Despite the availability of techniques to estimate the economic value of non-market goods and services, these techniques cannot begin to estimate the full values of all goods and services. For example, we need more comprehensive estimates of the forest contributions of water, forage, wildlife, recreation, and the other diffuse ecological and environmental services rather than only their marketable aspects. For this reason, we need physical as well as monetary accounts to assess actual capacity. Physical accounts are also required because they are not affected by market prices and other short-term factors, and they can be used to directly monitor long-run changes in the actual capacity of forest assets.

2. *Potential Capacity Accounts*

The goal of the Potential Capacity Accounts is to realistically track the various ecosystem features that underpin both actual capacity, as well as the future or potential benefits of those features. Such accounts might first track obvious features of ecosystems such as the extent and condition of various flora, fauna, soil, water, air, and climate, which are presumably affected by economic activities. But more explanatory economic-ecological relationships are also needed, such as various quantitative and qualitative aspects of forest ecosystems that may be indicative of ecosystem health, stability, or probable ecosystem dysfunction.

Indicators of potential capacity might assess the integrative characteristics of ecosystems as opposed to their unique features. For example, ecologists may eventually be able to describe (at least in somewhat more detail than at present) the necessary and sufficient conditions for the tolerance of an ecosystem to various kinds of changes. Such descriptors would then provide a measure of a known integrative and undoubtedly important long-run potential. Or, ecologists may be able to describe the necessary conditions for sustaining soil productivity. This would provide a measure of a known and obviously important long-run potential—one that might be reversible if damaged. Or, ecologists may one day describe various ways of tracking species populations and distributions and their relations to health and stability. This is what the interest in biodiversity is all about. And while the significance of biodiversity is currently unclear, when it is understood in greater depth it will no doubt provide an important measure of long-run potentials.

Indicators for Potential Capacity Accounts might also link functional or structural characteristics of an ecosystem to ecosystem integrity. Net Primary Productivity (NP) is known to be functionally important to ecosystem integrity. Other indicators such as the distribution, size, and "connectedness" of various animal and plant populations or their habitats are thought to be structurally important to ecosystem health. Such functional and structural ecological and environmental indicators would monitor and indirectly measure the stability and sustainability of ecosystems, and guide our attempts at ecosystem management.

3. *Linkage Accounts*

The third part of this robust accounting system, Linkage Accounts, would attempt to tie together the Actual Capacity Accounts and Potential Capacity Accounts. As implied, Linkage Accounts would attempt to estimate the costs of various ecological imperatives to maintain some ecological indicators at specified levels or to avoid certain ecosystem losses and changes. These imperatives will probably originate from a combination of scientific judgments, collective moral or

ethical decisions, and aesthetic considerations. In a sense, such linkages would reflect any "tradeoffs" or losses in today's actual incomes due to the perceived need to maintain future potential.

We have identified three kinds of costs that may be included in the linkage accounts: (1) eco-constraint losses—the costs foregone to maintain some ecosystem feature or to meet some "inviolate" ecosystem requirements, (2) damage values—the cost of unavoidable and irreversible ecosystem damage (also an opportunity cost of sorts), and (3) maintenance costs—the cost to maintain ecosystem functions and structures upon which their own continued productivity (and our continued survival) rests. Maintenance accounts would track the equivalent expense of depreciating or depleting forest capital in terms of its actual capacity and may be further divided into: (a) preventive expenses—the costs to avoid certain kinds of "unacceptable" ecosystem damage due to economic actions, (b) repair cost—the costs to repair unavoidable but reversible ecosystem damage caused by economic action, and (c) replacement costs—the costs to replace unavoidable but reversible ecosystem features "worn out" by economic activities.

Because these costs will be assessed in terms of prices based on the utility and technology of the current generation[2], Linkage Accounts may be used to reflect the impacts on us of protecting long-run potentials. Conversely, to the extent that we do not succeed in protecting these potentials, such accounts may also be used to indicate the gains to current forest users at the expense of long-run forest potentials. In other words, Linkage Accounts translate the changes in long-run potentials into impacts on the current economy and welfare in terms of current prices or physical quantities.

However, we must remember that the economic values of future potentials are neither the prices of those potentials nor the depreciation charges against the actual capacity of forest capital because the current generation gets nothing from these potentials. Rather, the economic values of future potentials are the opportunity costs for sustainable development—the costs that current people are willing to pay for a better future and to fulfill future generations. For irreversible potentials, the best course is probably to leave them intact. And when this intervention and disturbance are unavoidable, the cost of the best alternative might provide an appropriate estimate of opportunity cost.

Finally, through Linkage Accounts, the impacts or costs to the ecosystem of maintaining current levels of economic activity are identified. Through this identification a case may be made for reducing current estimates of national income because of a decline in ecosystem health and productivity. Almost all these "costs" are ignored at present, and as a result, current "incomes" are exaggerated. In other words, current income may be unsustainable. By such a series of linked accounts, the tradeoffs between current and future generations are highlighted, helping to clarify the implications of development decisions and policies directed toward achieving sustainable forest management.

In sum, all three types of accounts of forest resources are used by various users for different purposes. A major advantage of this system is that it provides information in terms of both economic and ecological accounts and their linkages. This new framework will provide valuable and useful information for making many decisions and policies that require this information. The integrated and interrelated information provided by this resource accounting system will increase the efficiency of planning, policy making and management, especially in the long term.

SUMMARY

We have attempted to outline some of the shortcomings of the conventional natural resource accounts currently used. In addition, we have outlined some features a more useful accounting system ought to have. In the process, we developed a rough proposal that would build on current resource and economic accounts and add some missing features. Such a system of forest resource accounts is urgently needed to help us move toward actually achieving the sustainable forest management that is the cornerstone of professional forestry.

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[2]*Economic values include both* value in exchange *(market value) and* value in use *(willingness to pay), both of which are based on utilitarian theory.*

A key premise of our argument is that forest ecosystems should be viewed as natural capital in terms of their dual productive roles as ecosystems and as sources of raw material for economic activity. Achieving economic sustainability can then be viewed as a process of maintaining these productive capacities including both natural and human-made aspects and purposes. For as ecological science has advanced, we have learned that the future capacity of forests as capital ultimately depends on maintaining the integrity and diversity of forests as one kind of ecosystem among many.

If economic and ecological sustainability is to be achieved, a forest accounting system must deal with forests both as economic resources and as ecosystems; for ecological stability and health, however we may come to define them, are the basis of economic sustainability.

Therefore, to provide effective information about the trends of forest capital's dual capacities and the dynamics of forest ecosystems, a forest accounting system should include at least three types of accounts. First, we need a set of already familiar but enhanced economic indices to track all actual or currently known uses of forests in terms of their economic and welfare contributions to the current generation—the Actual Capacity Account.

Second, a set of ecological accounts and indicators is needed to attempt to track potentials through various indirect but largely ecological measures of forest components, structures, and functions—the Potential Capacity Account. We cannot identify these potentials directly, although we are justified in inferring that future generations will want many of the same things we do. Such potentials are important because they embody future productive capacity.

Finally, we need a set of linkage accounts that would attempt to measure various costs and other tradeoffs necessitated by the imperative to maintain current ecosystem capacities as best we can. We have not yet learned to create functioning and stable ecosystems and environment from "scratch" to repair with certainty those we have damaged. This final set would also be crucial because it would indicate the extent to which current measures of economic income, by not considering the losses suffered by ecosystems and the often irreversible nature of these losses, are exaggerated and not sustainable. Together, the Actual, Potential, and Linkage Accounts might help forest policy makers and managers better balance various needs of current and future peoples within limited ecosystemic and environmental possibilities.

LITERATURE CITED

Ahmad, Y.J.; El Serafy, S.; Lutz, E., eds. 1989. **Environmental accounting for sustainable development**. Washington, DC: The World Bank. 100 p.

Anielski, M. 1991. **Natural resource accounting: operationalizing sustainable development**. A discussion paper of the Resource Accounting Project working group. Alberta, Canada: Alberta Forestry, Lands and Wildlife. 19 p.

Anielski, M. 1993. **Natural resource accounting: Alberta's forest account in 1991**. Corporate Services & Strategic Planning, Alberta Environmental Protection, March 1993. 39 p.

Avers, P.E. 1992. **Introduction**. In: Taking an ecological approach to management. Proceedings national workshop; 1992 April 27-30; Salt Lake City, UT. 241 p.

Bartelmus, P. 1989. **Environmental accounting and the system of national accounts**. In: Ahmad, Y.J.; El Serafy, S; Lutz, E., eds. Environmental accounting for sustainable development. Washington, DC: The World Bank: 79-87.

Bartelmus, P.; Lutz, E.; Schweinfest, S. 1992. **Integrated environmental and economic accounting: a case study for Papua New Guinea**. Environ. work. pap. 54. Washington, DC: The World Bank, Environment Department. 57 p.

Bishop, R.C. 1987. **Economic value defined**. In: Decker, D.J.; Goff, G.R., eds. Valuing wildlife: economic and social perspectives. San Francisco, CA: Westview Press. 424 p.

Brown, Greg; Harris, C.C. 1992. **The U.S. Forest Service: toward the new resource management paradigm**? Society and Natural Resources. 5(3): 231-245.

Costanza, R.; Daly, H. 1990. **Natural capital and sustainable development**. In: Bradley, D.P.; Nilsson, P.O., eds. Ecological economics: its implications for forest management and research: proceeding of a workshop; 1990 April; St. Paul, MN. Garpenberg, Sweden: The Swedish University of Agriculture. 239 p.

Daly, H.E. 1991. **Sustainable development: from concept and theory towards operational principles**. In: Steady-state economics, 2d ed. Washington, DC: Island Press: 241-260.

Daly, H.E.; Cobb, J.B., Jr. 1989. **For the common good: redirecting the economy toward community, the environment, and a sustainable future**. Boston, MA: Beacon Press. 482 p.

Dunlap, R.E.; van Liere, K.D. 1984. **Commitment to dominant social paradigm and concern for environmental quality**. Social Science Quarterly. 65: 1013-1028.

El Serafy, Salah. 1991. **The environment as capital**. In: Costanza, Robert, ed. Ecological economics: the science and management of sustainability. New York: Columbia University Press: 168-175. Chapter 12.

El Serafy, Salah; Lutz, E. 1989. **Environmental and resource accounting: an overview**. In: Ahmad, Y.J.; El Serafy, S.; Lutz, E., eds. Environmental accounting for sustainable development: A UNDP-World Bank symposium. Washington, DC: The World Bank: 1-7.

FEMAT. 1993. **Forest ecosystem management: an ecological, economic, and social assessment**. Report of the Forest Ecosystem Management Assessment Team. July, 1993. USDA FS, USDI FWS, USDI PS, USDI BLM, USDC NOAA, and NMFS, and EPA.

Foy, G.E. 1991. **Accounting for non-renewable natural resources in Louisiana's gross state product**. Ecological Economics. 3 (1991): 25-41.

Gilbert, A.J.; Hafkamp, W.A. 1986. **Natural resource accounting in a multi-objective context**. Journal of Regional Science. 20(3): 10-37.

Hicks, J. 1946. **Value and capital: an inquiry into some fundamental principles of economic theory**. Oxford: Oxford University Press. 340 p.

Hicks, J. 1974. **Capital controversies: ancient and modern**. American Economic Review. 64: 301-316.

Hueting, R. 1974. **New scarcity and economic growth**. New York: North-Holland Publ. Co. 269 p.

Hueting, R. 1980. **New scarcity and economic growth: more welfare through less production**? Amsterdam: North-Holland Publ. Co. 269 p.

International Union for Conservation of Natural Resources (IUCN), United Nations Environment Programme (UNEP), and World Wildlife Fund for Nature (WWF). 1991. **Caring for the earth: a strategy for sustainable living**. In: 2d World conservation strategy. Gland, Switzerland. 228 p.

Johnson, R.L.; Johnson, G.V., eds. 1990. **Economic valuation of natural resources: issues, theory, and applications**. Boulder, CO: Westview Press: 67-77.

Olson, M. 1977. **The treatment of externalities in national income statistics**. In: Wingo, L.; Evans, A., eds. Public economics and the quality of life. Baltimore, MD: Johns Hopkins University Press: 219-246.

Overbay, J.C. 1992. **Ecosystem management**. In: Taking an ecological approach to management, proceedings of national workshop; 1992 April 27-30; Salt Lake City, UT: 3-15.

Peskin, H.M. 1981. **National income accounts and the environment**. Natural Resources Journal. 21: 511-537.

Peskin, H.M. 1989. **A proposed environmental accounts framework**. In: Ahmad, Y.J.; El Serafy, S.; Lutz, E., eds. Environmental accounting for sustainable development: A UNDP-World Bank symposium. Washington, DC: The World Bank: 40-53.

Peskin, H.M. 1990. **A survey of resource and environmental accounting in industrialized countries**. Environ. Work. Pap. 37. Washington, DC: Environment Department, The World Bank. 26 p.

Peterson, G.L.; Randall, A., eds. 1984. **Valuation of wildland resource benefits**. Boulder, CO: Westview Press. 258 p.

Repetto, R. 1992. **Accounting for environmental assets**. Scientific American. June, 1992: 94-100.

Repetto, R.; Marath, W.; Wells, M.; Beer, C.; Rossini, F. 1989. **Wasting assets: natural resources in the national income accounts**. Washington, DC: World Resources Institute. 68 p.

Solow, R. 1992. **An almost practical step toward sustainability**. An invited lecture on the occasion of the 40th anniversary of Resources for the Future. Washington, DC. October 8, 1992.

Theys, J. 1989. **Environmental accounting in development policy: the french experience**. In: Ahmad, Y.J.; El Serafy, S.; Lutz, E., eds. Environmental accounting for sustainable development: A UNDP-World Bank symposium. Washington, DC: The World Bank: 40-53.

USDA Forest Service. 1990a. **Report of the Forest Service: fiscal year 1990**. Washington, DC: U.S. Department of Agriculture, Forest Service. 220 p.

USDA Forest Service. 1990b. **The Forest Service program for forest and rangeland resources: a long-term strategic plan**. Washington, DC: U.S. Department of Agriculture, Forest Service.

USDA Forest Service. 1992. **Taking an ecological approach to management**. Proceedings of a national workshop; 1992 April 27-30; Salt Lake City, UT. WO-WSA-3. Washington, DC: U.S. Department of Agriculture, Forest Service, Watershed and Air Management. 241 p.

Wilkerson, O.L.; Edgell, M.C.R. 1993. **The role and limitations of paradigm research in environmental management**. In: Foster, H.D., ed. Advances in resource management. London: Belhaven Press: 53-83.

Xu, Z.; Bradley, D.P. 1993. **Forests as natural capital: a survey of issues**. Manuscript in review.

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Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.

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